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EXCITED STATES IN THE DOUBLY CLOSED SHELL NUCLEUS $^{132}_{50}\text{Sn}_{82}$

T. Björnstad^{a)}, J. Blomqvist^{b)}, G.T. Ewan^{c)}, B. Jonson^{a)},
K. Kawade^{d)}, A. Kerek^{b)}, S. Mattsson^{a)} and K. Sistemich^{e)}.

The ISOLDE Collaboration, CERN, Geneva, Switzerland

- a) CERN-ISOLDE, CERN, CH-1211 Geneva 23, Switzerland
- b) Research Institute for Physics, S-10405 Stockholm, Sweden
- c) Queens University, Dept. of Physics, Kingston, Ontario,
Canada K7L 3N6.
- d) Nagoya University, Nagoya, Japan
- e) Institut für Kernphysik, Kernforschungsanlage Jülich,
D-5170 Jülich.

ABSTRACT

New excited states in the nucleus ^{132}Sn have been identified from $\gamma\gamma$ coincidence measurements. Strong beta feeding to a state at 7210 keV was established. This level is interpreted as a 6^- state formed after a $\pi g_{9/2}^{-1} \rightarrow \nu g_{7/2}^{-1}$ GT β^- transition from the 7^- ground state of ^{132}In . The deexcitation of the 7210 keV state passes through a 4351 keV state, providing support for a 3^- assignment of this level.

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The first information about the level structure in the doubly-magic nucleus ^{132}Sn came from experiments on the β^- decay of ^{132}In [1]. A γ transition with the energy 4041 keV was interpreted to represent the deexcitation of the first excited state in ^{132}Sn . Later, this state was found to be the lowest of a series of four excited states, where the highest state at 4847 keV is an isomer with the half-life 1.7(2) μs [2]. The latter experiment was performed at the recoil fission product separator JOSEF in Jülich. The multipolarity of the 132 keV transition deexciting the isomer was deduced to be E2 based on intensity balance arguments. In a conversion electron experiment at ISOLDE [3], the multipolarity E2 was also found for the 299 keV and 375 keV transitions (see Fig. 1).

Recently, the half-lives of the 4715 keV and 4416 keV states have been measured in Jülich to be 20.2(1.6) ns and 4.0(0.3) ns (cf. note below), respectively. These values give good support for the E2 assignments based on the conversion electron measurement. The results mentioned above strongly suggest that the states observed in the Jülich experiments [2] form an $8^+ \rightarrow 6^+ \rightarrow 4^+ \rightarrow 2^+ \rightarrow 0^+$ sequence.

The γ spectrum from the ^{132}In β^- decay obtained at ISOLDE showed as a further interesting feature a strong γ line at 4351 keV, which was absent in the γ spectrum from the deexcitation of the 1.7 μs isomer. This line is a strong candidate for the $3^- \rightarrow 0^+$ ground state transition, which is predicted at about this energy from level systematics [1] and RFA calculations [4].

According to the shell model, the first neutron and proton-hole orbitals outside the $(N,Z) = (82,50)$ core are $2f_{7/2}$ and $1g_{9/2}$, respectively. With a δ -force [1] the 7^- member of the $(\nu f_{7/2}^{-1}, \pi g_{9/2}^{-1})$ configuration becomes the ground state of ^{132}In . This assignment also follows from Nordheim's third rule [5]. Further support for the assumption that the state with $J = j_p + j_h - 1$ comes lowest in energy derives from a comparison with the particle-hole configuration $(\nu f_{5/2}^{-1}, \pi h_{9/2})$ in ^{208}Bi , where all members of

Note : From an earlier experiment a somewhat lower value had been deduced [3].

the multiplet are known. The β^- decay should proceed mainly by an allowed Gamow-Teller transition $(\nu f_{7/2}, \pi g_{9/2}^{-1})_{7^-} \rightarrow (\nu f_{7/2}, \nu g_{7/2}^{-1})_{6^-}$. In this letter we report on new experimental data, which show strong evidence for the feeding of a 6^- state at 7210 keV, and also supports the 3^- assignment of the 4351 keV state [3].

The experiment was performed at ISOLDE, CERN, where the indium activity was produced in an uranium carbide target bombarded with 600 MeV protons [3]. Multispectrum analysis measurements were performed with an 18% Ge(Li) detector. The experiment showed a number of new transitions in ^{132}Sn following the β^- decay of ^{132}In (Fig. 1), and gave in addition the new value $T_{1/2} = 0.19(2)$ s for the half-life of ^{132}In . $\gamma\gamma$ coincidence measurements were performed with two Ge(Li) detectors with standard efficiencies 6 and 18%. Parallel production of 6.5 d ^{132}Cs , in a yield about four orders of magnitude higher, severely complicated the experimental conditions. Clear coincidences were, however, found for the strongest transitions and from these data the decay scheme shown in Fig. 1 could be constructed.

The new level at 7210 keV is most likely the expected $(\nu f_{7/2}, \nu g_{7/2}^{-1})_{6^-}$ state. The feeding β^- transition has $\log ft = 4.5(1)$, which is of comparable strength as the elementary $\pi g_{9/2}^{-1} \rightarrow \nu g_{7/2}^{-1}$ transition in the β^- decay of ^{131}In [6]. The reduced GT transition rates to the $(\nu f_{7/2}, \nu g_{7/2}^{-1})_J$ states in ^{132}Sn should be

$$((7/2 \ 7/2)_J, 1, 7 \mid 7/2, (7/2 \ 1)9/2, 7)^2 = \begin{cases} 8/9 & \text{for } J=6 \\ 1/9 & \text{for } J=7 \end{cases}$$

in units of the single-hole rate. The predicted small fractional yield to the $J=7$ state explains why this β^- decay branch has not been observed.

The gamma decay of the $(\nu f_{7/2}, \nu g_{7/2}^{-1})_{6^-}$ state is expected to proceed by E2 transitions to $(\nu f_{7/2}, \nu d_{3/2}^{-1})_J$ states, analogous to the simple $\nu g_{7/2}^{-1} \rightarrow \nu d_{3/2}^{-1}$ gamma decay in ^{131}Sn [6] by a 2.4 MeV E2 transition. The reduced E2 transition rates in ^{132}Sn should be

$$((7/2 \ 3/2)_J, 2, 6 \mid 7/2, (3/2 \ 2)7/2, 6)^2 = \begin{cases} 3/5 & \text{for } J=4 \\ 2/5 & \text{for } J=5 \end{cases}$$

in units of the single-hole rate. The observed intensity ratio of the 2380 keV and 2268 keV gamma lines

$$I(2380)/I(2268) = 1.6(2)$$

makes it highly probable that these transitions proceed to the 4^- and 5^- states, respectively. Configuration mixing effects are not likely to change this conclusion. The order of and even the spacing between these two members of the $(\nu f_{7/2}, \nu d_{3/2}^{-1})$ multiplet conform with the analogous case of the $(\nu g_{9/2}, \nu f_{5/2}^{-1})$ multiplet in ^{208}Pb , where the 6^- (3919 keV) and 7^- (4037 keV) states are separated by 118 keV.

The decay of the 4^- state is expected to go by a rather fast M1 transition to the lowest 3^- state, which is a collective mixture of many particle-hole configurations [4], but with $(\nu f_{7/2}, \nu d_{3/2}^{-1})$ as one of the main components. The only interpretation of the observed 479 keV - 4351 keV cascade, which is consistent with firm theoretical predictions, is the $4^- \rightarrow 3^- \rightarrow 0^+$ alternative. Direct experimental proof of the 3^- assignment is, however, lacking.

The β^- decay of ^{132}In can also proceed by 1st forbidden transitions of the types $\pi g_{9/2}^{-1} \rightarrow \nu h_{11/2}^{-1}$, $\nu f_{7/2} \rightarrow \pi d_{5/2}$ and $\nu f_{7/2} \rightarrow \pi g_{7/2}$. The first of these would mainly lead to the $(\nu f_{7/2}, \nu h_{11/2}^{-1})_{8^+}$ configuration, which is the dominant component of the 4847 keV isomeric state. The observed feeding of this state gives $\log ft = 5.2(1)$, which is a rather low but not unreasonable value for an unhindered 1st forbidden transition. The $\log ft$ value of the elementary $\pi g_{9/2}^{-1} \rightarrow \nu h_{11/2}^{-1}$ transition in the β^- decay of ^{131}In [6] is unfortunately not known. The transitions to the other $(\nu f_{7/2}, \nu h_{11/2}^{-1})_J$ states with $J=6,7$ should be considerably retarded by geometrical factors

$$((7/2 \ 11/2)_J, 1, 7 \mid 7/2, (11/2 \ 1)9/2, 7)^2 = \begin{cases} \frac{8}{1232} & \text{for } J=6 \\ \frac{153}{1232} & \text{for } J=7 \\ \frac{1071}{1232} & \text{for } J=8 \end{cases}$$

The other two types of 1st forbidden β^- transitions from the $(\nu f_{7/2}, \pi g_{9/2}^{-1})_{7^-}$ state of ^{132}In are expected to go mainly to $(\pi g_{7/2}, \pi g_{9/2}^{-1})_{7^+}$ and $(\pi d_{5/2}, \pi g_{9/2}^{-1})_{6^+}$ states in ^{132}Sn . The excitation energies of these

states are estimated to be about 5.5 MeV(7^+) and 6.5 MeV(6^+). Based on the known β^- decay rate of ^{133}Sn [7] the branch into these two states should together amount to about 10% of the total decay. No evidence for this has been found in the present experiment.

The positive parity states in Fig. 1 are connected by E2 transitions. The experimental reduced rates of the $8^+ \rightarrow 6^+$, $6^+ \rightarrow 4^+$ and $4^+ \rightarrow 2^+$ transitions are compared in Table 1 with calculated values, assuming pure $(\nu f_{7/2}, \nu h_{11/2}^{-1})$ configurations. The good agreement indicates that these states are indeed mainly of $(\nu f_{7/2}, \nu h_{11/2}^{-1})$ character.

The emerging picture of ^{132}Sn is that of a nucleus with exceptionally strong shell closures. The first few negative-parity particle-hole excitations, collective as well as non-collective, occur at considerably higher energies in ^{132}Sn than in ^{208}Pb , even allowing for an $A^{-1/3}$ scaling. A detailed comparison of the properties of these two closely related nuclei should be instructive. The results presented here are not complete. We hope that further experimental studies may be able to confirm the present interpretation and provide data on new levels in ^{132}Sn .

REFERENCES

- [1] Kerek, A., Holm, G.B., De Geer, L.-E. and Borg, S., Phys. Lett. 44B 252 (1973).
- [2] Lauppe, W.-D., Sistemich, Khan, T.A., Lawin, H., Sadler, G., Selić, H.A. and Schult, O.W.B., Proc. Int. Conf. Nuclear Structure, Tokyo 1977, J. Phys. Soc. Japan 44, suppl. p. 335 (1978).
- [3] Björnstad, T., De Geer, L.-E., Ewan, G.T., Hansen, P.G., Jonson, B., Kawade, K., Kerek, A., Lauppe, W.-D., Lawin, H., Mattsson, S. and Sistemich, K., Phys. Lett. 91B, 35 (1980).
- [4] Dehesa, J.S., Lauppe, W.-D., Sistemich, K. and Speth, J., Phys. Lett. 74B, 309 (1978).
- [5] Brennan, M.H. and Bernstein, A.M., Phys. Rev. 120, 927 (1960).
- [6] De Geer, L.-E. and Holm, G.B., Phys. Rev. C22, 2163 (1980).
- [7] Borg, S., Holm, G.B. and Rydberg, B., Nucl. Pys. A212, 197 (1973).

Table 1

Comparison of experimental and theoretical $B(E2)$ rates, expressed in single-particle units $B_W(E2) = 40 e^2 \text{fm}^4$. The theoretical values are calculated for pure $(\nu f_{7/2}, \nu h_{11/2}^{-1})$ configurations, assuming $e_{\text{eff}} = e$ and the radial matrix elements $\langle r^2 \rangle_f = \langle r^2 \rangle_h = 33 \text{ fm}^2$.

Transition	$B(E2)$ exp	$B(E2)$ th
$8^+ \rightarrow 6^+$	0.13	0.11
$6^+ \rightarrow 4^+$	0.28	0.24
$4^+ \rightarrow 2^+$	0.41	0.19

Fig. 1 : Level scheme of ^{132}Sn . Energies are given in keV.
Relative gamma intensities are given in parenthesis.